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ABSTRACT

This report develops a model of a personal computer network for office use from the standpoint of the end user. A network designed for personal computers is differentiated from personal computers which must be attached to an existing communications system. Three types of the latter networks are discussed: (1) networks which connect personal computers to personal computers, personal computers to computer centers, and personal computers to bulletin boards by means of public and private telephone systems; (2) networks which connect personal computers to computer centers by means of direct wire in the same manner that terminals are directly connected to computer centers; and (3) networks which connect personal computers to networks designed for large computers. Each personal computer network type is compared, according to level of service provided, to a model which embodies the needs and expectations of personal computer users. The generic types of service used for the comparison include file and print service; mail; messaging and conferencing; login; remote task execution; outside communication; and network configuration. A discussion of options available to those who have an immediate need for a personal computer network is also presented. The text is supplemented with 8 tables and 11 figures, and a list of 27 references is provided. (Author/EW)

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NBS Special Publication 500 – 140

Personal Computer Networks

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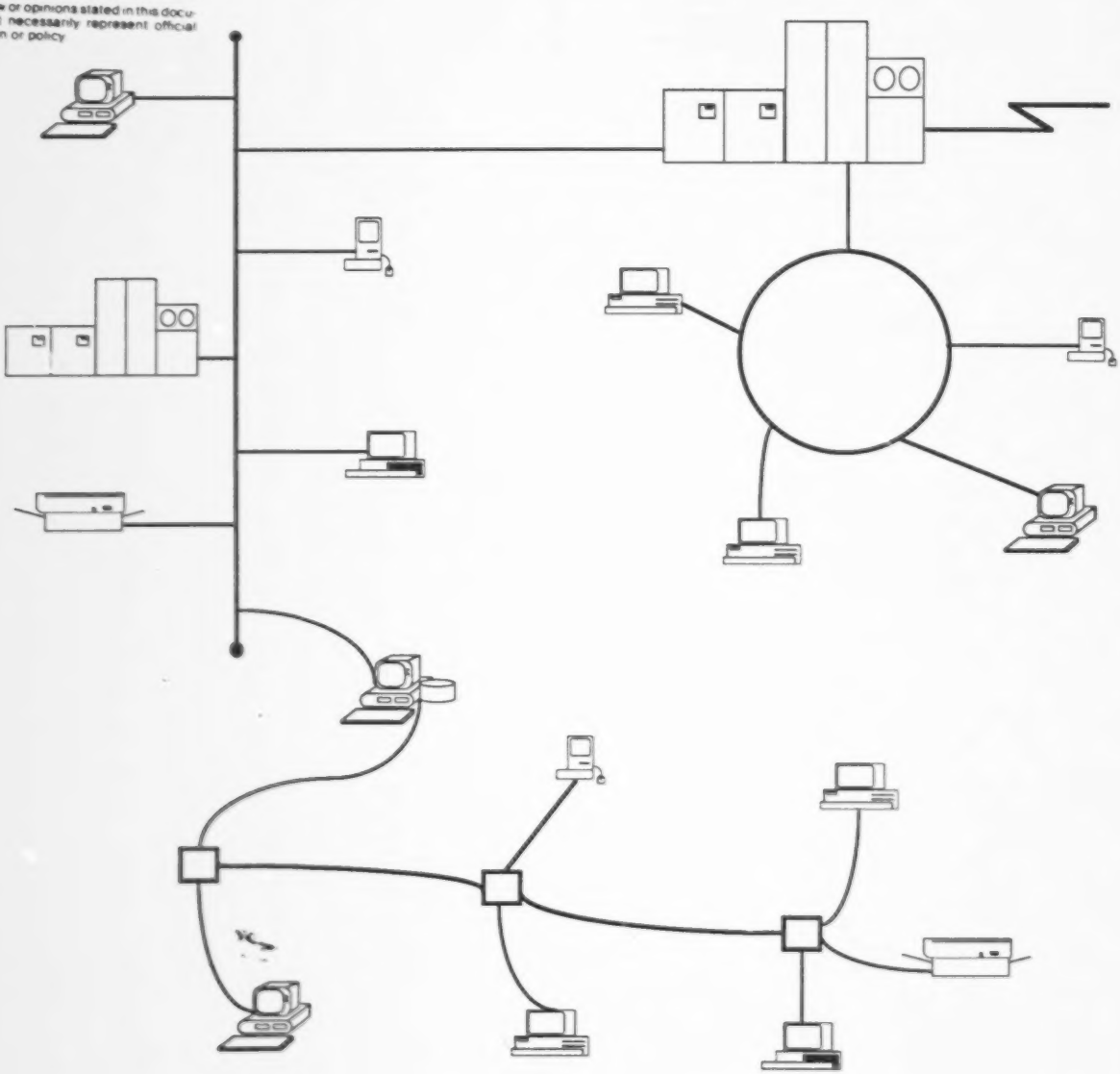

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Computer Science and Technology

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Personal Computer Networks

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ABSTRACT

Personal computers are widely used in today's office to support clerical, administrative, and managerial functions. Because communication between individuals in a office and between groups in an organization is vital to the organization's ability to deliver products and services, it naturally follows that the personal computers used by the individuals in an office need to be able to communicate. This organizational requirement for communications is often met by networking personal computers.

Personal computer networks are grouped into those networks which are designed for personal computers and those networks, such as those based on a telephone system, which can connect personal computers but were designed for a different purpose. Networks which can connect personal computers but were designed for a different purpose include: networks which connect personal computers to personal computers, personal computers to computer centers, and personal computers to bulletin boards by means of public and private telephone systems; networks which connect personal computers to computer centers by means of direct wire in the same manner that terminals are directly connected to computer centers; and networks which connect personal computers to networks designed for large computers.

A personal computer network model, which embodies the needs and expectations of personal computer users, is described. Each personal computer network type is compared to this model according to the level of service provided. The generic types of service used for the comparison include: file and print service, mail, messaging and conferencing, login, remote task execution, outside communication, and network configuration.

A discussion of options available to those who have an immediate need for a personal computer network is presented. Personal computer networks can improve productivity in the office. However, there is the possibility of installing a personal computer network which in the future becomes isolated from the mainstream of networking technology. Informed planning can prevent this isolation from happening.

Contents

1 Introduction 1

2 A Personal Computer Network Model 7
- 2.1 File Service . . . 7
- 2.2 Print Service . . . 9
- 2.3 Mail . . . 9
- 2.4 Messaging and Conferencing . . . 10
- 2.5 Login . . . 10
- 2.6 Remote Task Execution . . . 10
- 2.7 Outside Communications . . . 11
- 2.8 Network Configuration . . . 11

3 Ad Hoc Personal Computer Networks 13
- 3.1 Telephone Systems . . . 14
- 3.2 Direct Wire to Computer Center . . . 18
- 3.3 Network Designed for Large Computers . . . 19

4 Networks Designed for Personal Computers 21
- 4.1 Comparison with Network Model . . . 21
- 4.2 Implementations . . . 23
  - 4.2.1 Servers . . . 23
  - 4.2.2 Services Provided without Servers . . . 25
  - 4.2.3 Configuration . . . 26
  - 4.2.4 Other Characteristics . . . 31

5 Summary 39
- 5.1 Current Implementations . . . 39
- 5.2 Future Implementations . . . 42
- 5.3 Networking Now . . . 44

A References and Related Reading 47

B Personal Computer Network Testbed 51

List of Tables

1.1 Comparison of networks designed for large computers and networks designed for personal computers 5

3.1 Features of a personal computer to personal computer network 16
3.2 Features of a personal computer to computer center network 17
3.3 Features of a personal computer to bulletin board network 18
3.4 Features of a direct wire to computer center network 19
3.5 Features of a network designed for large computers 20

4.1 Features of a network designed for personal computers 22

5.1 Features of current personal computer networks 40

List of Figures

1.1 Catagorization of personal computer networks 3
1.2 Example of a personal computer network in an office suite used by a small group 4

2.1 Copying *myfile* from virtual disk on File Server 8

4.1 User connected to two personal computer networks 28
4.2 Two *logical networks* on the same physical link 29
4.3 Communications server connecting two networks 31
4.4 Personal computer network hardware model 32
4.5 Internal and external network interfaces 33
4.6 Communication backbone cable topologies 34
4.7 Connecting the interface with a bus backbone 35

B.1 Personal computer network testbed in the Advanced Systems Laboratory . 53

Chapter 1

Introduction

Personal computers are widely used in today's office to support clerical, administrative, and managerial functions. Because communication between individuals in a office and between groups in an organization is vital to the organization's ability to deliver products and services, it naturally follows that the personal computers used by the individuals in an office need to be able to communicate. This organizational requirement for communication is often met by networking personal computers.

This document presents a survey of personal computer network technology from the point of view of the end user. It characterizes the capabilities of personal computer networks and the services which they provide the user in terms of generic features which are available from many producers. As a result, technical management and end users will have an understanding of how personal computer networks can fit into an overall office automation strategy. The document does not discuss or evaluate alternatives for the sharing of data, such as the manual exchange of floppy disks between personal computers.

The information contained in this document is partially based on experience gained from the personal computer network testbed in the Advanced Systems Laboratory of the Institute for Computer Sciences and Technology (ICST) at the National Bureau of Standards. Additional experience was obtained from the installation and operation of two large personal computer networks within the ICST used to support both experimental and administrative applications.

The network testbed in the Advanced Systems Laboratory consists of several different sets of network hardware on which many different network software packages may be run. Network hardware includes baseband CSMA/CD, broadband CSMA/CD, baseband CSMA/CA, and token ring (see Tanenbaum text cited in Appendix A for explanation of terms). In addition to the several personal computer networks within the Laboratory, access is also provided from the Laboratory to both a personal computer network and a large computer network available throughout the ICST. The large computer network provides access to the Department of Defense MILNET (formally known as the ARPANET) through a minicomputer gateway. Appendix B shows the personal computer network testbed as it is normally configured. The testbed at any given time may be reconfigured

for special projects.

For the purposes of this document, a *personal computer network* is loosely defined as a communications system to which a personal computer can be connected and which provides a means of transferring data from one personal computer to another. Thus, if personal computers are connected to an existing communications system, such as a telephone system or a network designed for large computers, this network qualifies as a personal computer network. However, attaching personal computers to an existing communications system is to be distinguished from a network which was specifically designed for personal computers. In order to distinguish these two approaches to accomplishing personal computer networking, the term *network designed for personal computers* is used to refer to personal computer networks which were designed specifically to meet the needs of personal computer or workstation users. There can be a huge difference in the kind of service which results from connecting a personal computer to an existing communication system as opposed to connecting a personal computer to a network designed for personal computers.

Personal computer networks which are implemented by connecting personal computers to existing communication systems are referred to in this document as *ad hoc* personal computer networks. Ad hoc personal computer networks consist of networks built upon telephone systems (both public and private), networks built by connecting personal computers to a computer center by direct wire as is done with terminals, and networks designed for large computers. Figure 1.1 summarizes the catagorization of personal computer networks that is used in this document.

As parts of an office automation system, personal computers must be able to communicate with other personal computers and with other elements of an office system, such as mainframes and minicomputers. Since mainframes are multi-user systems, mainframe users can share information by sharing files on the mainframe. On the other hand, the personal computer is usually a single-user system; however, the personal computer user often has the same requirements for information sharing as the mainframe user. The personal computer user must be able to share information with not only other personal computer users but also with the other users of their office automation system.

In addition to sharing information, personal computer users, like their mainframe counterparts, need to be able to share expensive peripheral equipment, such as high speed printers, high quality printers, and large mass storage. In cases where only a limited standalone capability is required, the personal computer may have no peripherals at all, i.e., a personal computer with only a keyboard, display, cpu, and memory. The personal computer relies on other nodes of the network for its peripherals: disk storage is provided by another system on the network; software is downloaded from a disk on a remote system; data storage is provided by means of a disk on a remote system; files to be printed are sent to a printer attached to a remote system.

The personal computer user often needs access to other information resources, such as local computer centers, remote timesharing services, and telephone systems. A personal computer network can provide *gateways* to these other resources so that the personal computer need only be connected to a single communication system. These gateways can

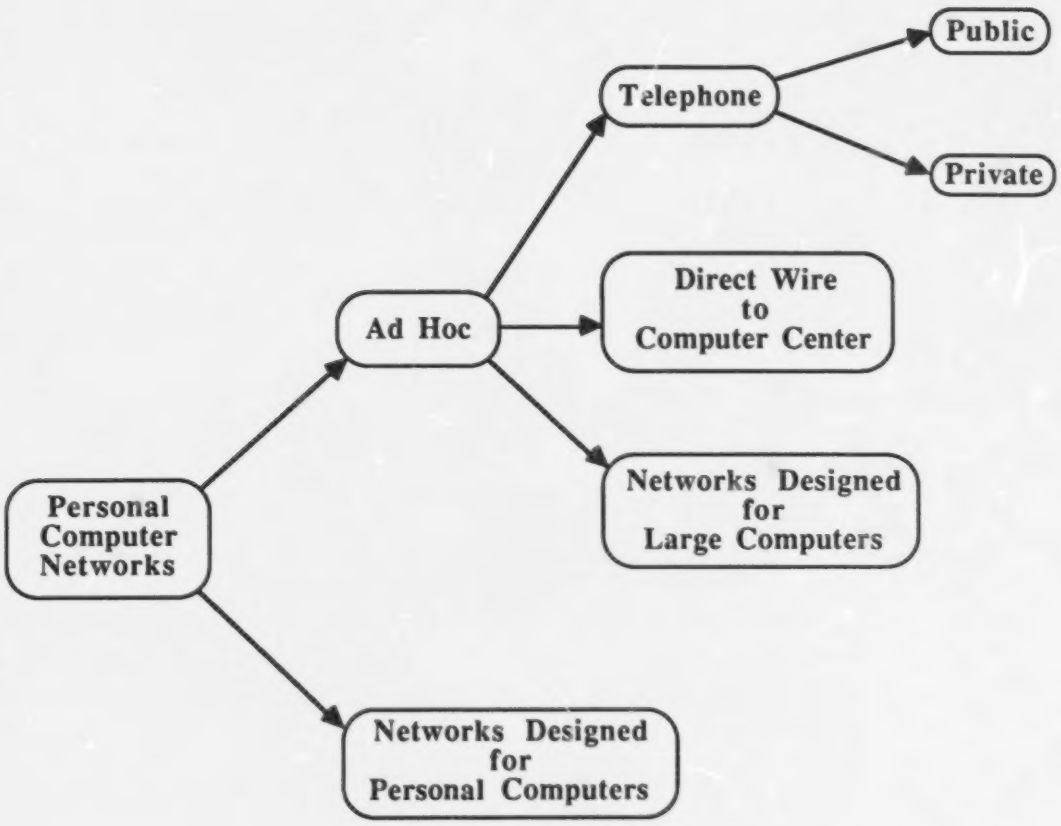

Figure 1.1: Catagorization of personal computer networks

also provide access to other networks which may have different communications protocols. In this case, gateways provide not only the connection but also any necessary protocol conversion between incompatible networks. Figure 1.2 shows a floor plan of a suite of offices belonging to a small group in which a personal computer network is used to share data (File Server), peripherals (disk on the File Server and the Laser Printer), and provide each user with access to other communication systems (Communication Server).

For the purposes of comparison, computer networks can be classified according to the types of devices they were designed to interconnect. The first computer networks were designed to interconnect large multi-user computers and their terminals. Networks have been designed which are primarily for the interconnection of personal computers. In some cases, these networks do not support the connection of large computers and terminals.

For the purposes of this document, computer networks are divided into two types: wide area networks and local area networks. A local area network (LAN) refers to a network which interconnects systems located in a small geographic area, such as a building or a

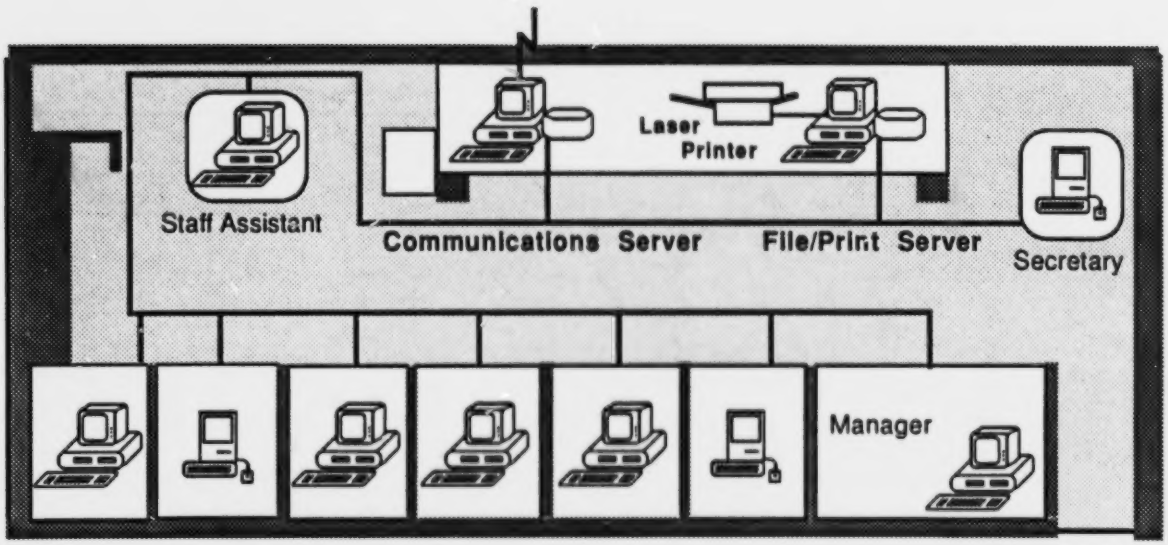

Figure 1.2: Example of a personal computer network in an office suite used by a small group

complex of buildings. A wide area network (WAN) refers to a network which interconnects systems located in a large geographic area, such as a city, a continent or several continents.

It is interesting to contrast how a computer network designed for personal computers differs from a computer network designed for large computers. These differences as summarized in Table 1.1 include:

- Size of System at Each Node

  Networks designed for large computers connect large multi-user mainframe and minicomputer systems. Networks designed for personal computers connect personal computers which are usually small, single user systems. The capabilities of the computer system at each node influence the kind of services which the network delivers. Many of the services provided to large system users are not available to personal computer users. One example of this is print spooling. When mainframe users print a file, the file is queued to a printer and users are immediately able to continue their work without waiting for the file to be printed. In addition, print spooling allows mainframe users to share expensive printers. Personal computer users also should not have to wait until the printer is finished before continuing. Moreover, personal computer users need to be able to share expensive printers. Thus, print spooling is a good candidate for a service which could be provided by the network.

- Network Type

  Networks designed for large computers can be either local area or wide area networks. However, almost all networks designed for personal computers are local area networks.

Characteristic	Large Computer	Personal Computer
Systems Connected	large, multi-user	small, single user
Network Type	WAN or LAN	LAN
Transmission Speed	kbits/sec to tens of Mbits/sec	kbits/sec to several Mbits/sec
Connection Cost	$thousands	$hundreds
Service Examples	login file transfer mail	remote device attachment messaging mail

Table 1.1: Comparison of networks designed for large computers and networks designed for personal computers

- Transmission Speed

  Because networks designed for large computers can connect several users at one node to several users at another node, the transmission speed between nodes must be large in order to provide good service. This is particularly true where the network designed for large computers is a local area network. When the network is a wide area network, service often suffers because high speed transmission over great distance is very costly and, as a result, may not be provided.

  In a network designed for personal computers, only a single user per node must be serviced. As a result, a slower transmission speed may be adequate, since the number of users on a network designed for personal computers is usually smaller than the number of users on a network designed for large computers. Transmission speeds in networks designed for large computers can be tens of megabits per second. Transmission speeds in networks designed for personal computers range from kilobits per second to several megabits per second.

- Connection Cost

  Since the systems at each node are multi-user and each node often requires a high speed connection to the network, the cost of the network interface in a network designed for large computers is sizable. An interface for a network designed for personal computers is considerably less costly. However, in both cases, the cost of the network interface can be a significant percentage of the total cost of the system at the node. The cost of a network interface for a personal computer can be greater than

50% of the cost of the personal computer for those personal computers which have no peripherals and rely on the network connection for access to disks and printers.

- Services Provided

  A user at a node of a network designed for large computers already shares information and peripherals with other users of that node by virtue of the fact that the node is a large multi-user system. Consequently, networks designed for large computers usually only provide three basic network services, i.e., login (i.e., remote terminal connection to a host), FTP (file transfer), and mail. The single user personal computer may require more flexible services, such as being able to access a remote virtual disk as though it were connected locally.

The remaining chapters cover the various aspects of personal computer networking in more detail. Chapter 2 describes a personal computer network model which represents a network which users can realistically and economically expect from current technology.

Chapter 3 and Chapter 4 discuss what is found in currently available personal computer networks. Chapter 3 characterizes ad hoc personal computer networks i.e., those which are built using communication systems already in place, such as telephone systems, networks designed for large computers, and systems used for terminal to computer center communications. Chapter 4 describes networks which were designed specifically for the interconnection of personal computers.

Chapter 5 summarizes how currently available personal computer networks fall short of users' expectations. It then provides scenarios which suggest how existing personal computer networks may evolve into the personal computer network model of Chapter 2. Finally, it describes how users can deal with the shortcomings of current personal computer networks. Appendix A lists references and related reading.

Chapter 2

A Personal Computer Network Model

Often, among the first things learned by personal computer users, is that having their own local computational capabilility is not sufficient. They also need to be able to exchange information electronically with other computer systems. Users may need to obtain data from other facilities, and they will probably want to make the results of their work accessible to others.

For example, a financial analyst needs access to an organization's financial reports kept on a central mainframe. Such data is necessary for assessing the reasons for the current financial state and for generating scenarios for future financial behavior. The analyst needs to be able to download this data to the personal computer where spreadsheet software is used for evaluation and generation of future projections. These results must be distributed to the analyst's management and peers for their review.

This chapter describes a personal computer network model that has the capabilities that a user might expect from a personal computer network today. The personal computer network described could be implemented from available technology, with the installation, connection, and usage costs consistent with the cost of personal computers. It comes as a surprise to many that this personal computer network model is not yet available off the shelf. The network model described in this chapter is meant to be an embodiment of a personal computer user's needs and expectations.

2.1 File Service

File service is fundamental to any computer network. However, the file service required of a personal computer network goes beyond that of being able to copy an entire file from one node to another. A personal computer may have limited disk storage and may need access to a file which is larger than its disk capacity.

As a result, a personal computer should to be able to attach to part of a remote mass storage device (i.e., a *virtual* disk) as though it were directly connected locally. All of

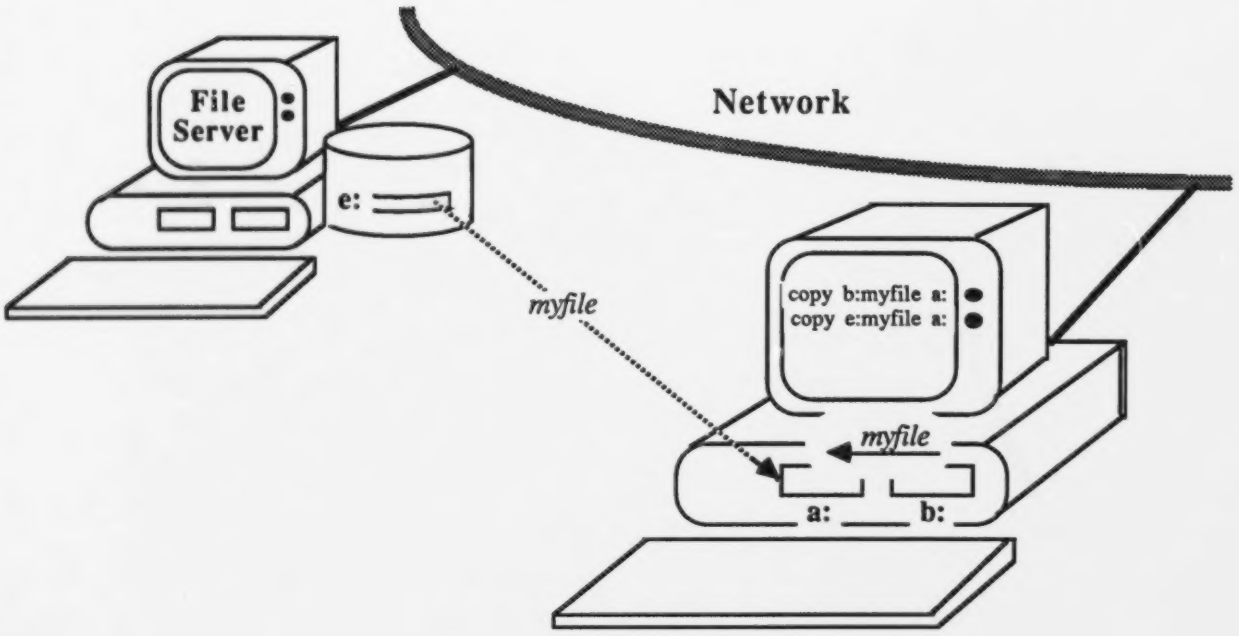

Figure 2.1: Copying *myfile* from virtual disk on File Server

the disk operations which can be done on a physically connected disk can be done on the remote virtual disk. For example, as illustrated in Figure 2.1, if the command "copy b:myfile a:" copies myfile from local disk b: to local disk a: and if disk e: is designated as a virtual disk drive on the server, then "copy e:myfile a:" transfers the file from the server to the personal computer.

Included in these disk operations is the capability for file/record locking. File/record locking gives a single personal computer the ability to have exclusive access to a file or record so that information may be read and modified in a single indivisible operation. Thus, several personal computers may operate concurrently in real time on a single large remote file. An example of such an application is inventory management. At the points of sale, personal computers are used to interrogate an inventory file to insure that an item is in stock. When the sale is made, the number of items sold is subtracted from the inventory data for that item.

File service includes the storage and downloading of software to personal computers. This is becoming increasingly important as application packages become larger and consume more disk space for both program and data storage. In addition to application packages, the file service is able to download operating system software so that the network supports *diskless* personal computers (i.e., personal computers with no disks directly attached). The remote diskless personal computer boots from the network.

2.2 Print Service

Print service on a personal computer network addresses two user needs: ongoing processing while printing and shared use of expensive printers. Since personal computers are usually single user, single task systems, when users want to print a file from their systems, they must wait for the printer to finish before they are able to use the system. However, the print service on the network accepts the file immediately and users are able to continue work on their personal computers without delay. The network acts as a spooler for print files. Print spooling refers to the ability of the network to queue print requests from users to the printer of choice.

The print service on the network also provides a means for users to easily share expensive high speed and/or high quality printers. Printers that are fast and/or can produce high resolution text and graphics are typically too expensive to be attached to each user's personal computer. By using the network, the user can have easy access to fast, high quality output. The use of a network print service does not preclude the use of small, inexpensive printer directly attached to personal computers for low quality, short printouts.

2.3 Mail

Mail service on the network is the electronic equivalent of the familiar hand carried mail. There are a number of different mail system prototypes, but in the context of this personal computer network model, mail service functions as follows:

> The network sends and receives text mail between nodes regardless of whether the node is a personal computer or a larger system. The mail is taken from the sender's personal computer at the time it is sent and within a short period of time, is delivered directly to the receiver system. If the receiver's system is not turned on or is otherwise occupied, the network retains the mail and tries periodically to deliver it. Mail is delivered directly to the receiver's system if that is what the receiver wishes; otherwise, the receiver obtains mail from a *mailbox* on the network. If desired, the receiver is notified without having to interrogate the network that mail has arrived. If desired, the sender is notified whether or not the mail has been delivered (i.e., after a pre-defined time, the mail is returned to the originator).

The functioning of mail described above is consistent with the manner in which mail services function on most large multi-user systems i.e., mail is delivered directly to the user's disk space and the user can be notified immediately upon the arrival of mail without having to interrogate a *post office*.

2.4 Messaging and Conferencing

Messaging refers to the ability of one user to send a short text message to another user and have the message delivered immediately. One user may enter text on a personal computer and that text is immediately displayed on another user's display if the other user wishes to see it. Conferencing refers to the ability of one user to send a text message to several other users simultaneously, i.e., to broadcast a message.

Unlike mail, messages which cannot be delivered are not retained by the network and the sender is informed of this fact. This service is the network equivalent of a telephone system with a conference call capability. The network can also record for later reference the dialogue of a message or conference session.

2.5 Login

In a network designed for large computers, login to a remote system is one of the services almost always provided. A user at a terminal logged into one of the multi-user system nodes on the network is able to login to a remote multi-user system as though the user were directly connected to the remote system. This personal computer network model also supports this capability except there are no dumb terminals, i.e., a personal computer is able to login to a remote multi-user system. In addition, the network supports the *login* of one personal computer to another remote personal computer. Logging into a remote personal computer means that the remote personal computer is being used as though the user were sitting at the keyboard of the remote.

One application of remote login to another personal computer might be the remote use of special hardware, such as a modem or an array processor installed in the remote. Users can access the special hardware remotely from their desks without having to sit at the personal computer to which the special hardware is attached. In addition to accessing remote hardware, a login capability can provide users with access to special software.

Because most personal computer software is licensed for use on a single system, a login capability means that only one copy of a software package need be purchased. A user runs the single copy of a software package on a remote personal computer by means of the login feature. This approach is to be distinguished from the execution of software packages by means of a file service. When using a file service, software is not executed on the system where it is stored but is downloaded to the user's system and is executed there. Thus, in most cases, a license must be obtained for each system which executes the software package.

2.6 Remote Task Execution

The network provides the capability of initiating the execution of a program or a job stream on a remote system. The job stream is expressed in the command language of the remote

system. In many cases, networks designed for large computers provide this service. This personal computer network model not only provides this service on remote large multi-user systems, but also provides remote task execution on remote personal computers. If a remote personal computer is enabled for remote task execution, it executes the application or job stream.

Remote task execution is different from login. As mentioned above, a user logged into a remote personal computer uses the remote system as though the user were sitting at the keyboard of the remote. Remote task execution means that the user sends a file of commands to be processed on a remote system. The network provides the means of transmitting the command file and receiving the results.

2.7 Outside Communications

The network provides access to communication systems external to the personal computer network (i.e., a communication system to which the personal computer is not directly connected), such as other networks and telephone systems. Thus, the network is a *gateway* to the outside world. It provides access to local computer centers, remote commercial timesharing and network services, videotex services, etc. However, the only services which are available through the gateway to another communication system are file transfer and login to remote large systems.

2.8 Network Configuration

The network is configurable in order to permit the distribution of services among its nodes. Distribution of services enhances network reliability and performance. In this personal computer network model, diagnostic tools are provided so that, in the event of a network failure, the problem can be easily located.

Configuration flexibility allows the establishment of limited access servers for small groups of users who need special or exclusive services. For example, only corporate planners may need to access a database of the geographic distribution of sales. Such a database could be set up on the personal computer of an individual planner rather than on a node which is configured to provide service to all network users. The configuration of such a node can be done by the users themselves. If the node goes down, only this group of users is affected and they are able move the database to another node used by one of their members.

Moreover, the configuration of these *special interest group* servers promotes information security by isolating the server from general access. Because the patterns of communication change over time among network users, the demands on network services change. Performance measuring tools which allow traffic patterns to be identified are provided. Configuration flexibility helps insure adequate service without a major addition of server hardware.

Not only is the network flexible in its configuration in order to permit responsive delivery of services, but it is also flexible in terms of the types of systems which can be attached as nodes. The network is able to provide its services to personal computers from different producers. This implies that the network provides conversion between the different file formats created by systems from different producers. The ability to transfer a file created on a system from one producer to a system from another producer is of little use if the file format is unintelligible to the system receiving the file.

In addition, to being able to connect personal computers from different producers, this personal computer network model supports the connection of mainframes and minicomputers from different producers. The disks and printers of these large systems can be attached as remote virtual devices, i.e., a large system on the network can provide file and print service to the personal computer users. Users logged into a large system on the network have access to the same network services that the personal computer user can access, e.g., login and remote task execution on either a remote large system or a remote personal computer.

Chapter 3

Ad Hoc Personal Computer Networks

Unfortunately, a personal computer network with the features of the model described in the previous chapter does not yet exist. There is no set of compatible commercial or public domain products which can be assembled to have all of the characteristics of the model without a considerable developmental effort on the part of the user.

Two broad categories of personal computer networks that can provide many of the features do exist, however. The first category consists of ad hoc personal computer networks. These are networks built on existing communication systems. This chapter examines the characteristics of existing personal computer networks in this category and the services which they provide. The second category consists of those networks designed for personal computers. Networks in this catagory are discussed in Chapter 4.

The tables in this chapter and those following compare the capabilities of both ad hoc personal computer networks and networks designed for personal computers to the features of the personal computer network model outlined in Chapter 2. The small "√" indicates that the full functionality of the feature may be available in some implementations but not usually. For example, all ad hoc personal computer networks provide file service by means of a simple file transfer capability. However, only a few permit the attachment of a remote virtual disk.

Ad hoc personal computer networks are assembled by adding personal computers to a communication system which was designed for a different purpose. Such networks can be an economical means to providing many of the required capabilities. Despite the rudimentary implementation of these capabilities in most cases, personal computer networks based on existing communication systems are invaluable to the user in the absence of more sophisticated approaches. Communication systems used as a basis for personal computer networks include telephone systems, direct wire to computer centers, and networks designed for large computers as discussed in Chapter 1.

In order for a personal computer network to be based on an existing communication system and provide a useful level of service, the following fundamental communication

problems must be addressed by either the communication system or by the hardware and software of the personal computer:

1. Flow Control

   Connected systems may differ with regard to the data transmission speeds that they are able to sustain. A transmitting system may send data faster than a receiving system is capable of accepting. For example, when data is transmitted from a personal computer to a mainframe, the mainframe may become busy with higher priority tasks and be unable to accept a large block of data from the personal computer. In order for successful communications to occur in these situations, the sending and receiving systems must have some means of temporarily suspending and then restarting the transmission of data.

2. Data Integrity

   There should be some assurance, at the time of transfer, that the data which was transmitted is the data that was received.

3. Transmission of Binary Data

   Many communication links are designed for transmitting 7 bit data only, i.e., those character codes defined in Federal Information Processing Standards Publication (FIPS PUB) 1-2. This precludes the possibility of sending 8 bit binary data. In order to transmit 8 bit binary data, the 8 bit data must be encoded into 7 bit data by the sender and subsequently decoded by the receiver.

If a telephone system is the communication system used for a personal computer network, the modem, personal computer, and its software must provide the solutions to these problems

3.1 Telephone Systems

Public and private telephone systems served as the basis for some of the first personal computer networks. Using a personal computer to connect to a telephone system provides access to outside communication services. If the public telephone system is used, then the personal computer may connect to almost any computer center or other communicaton network. Even if a private telephone system is used, this wide spectrum of potential connections exists because almost every private telephone system can connect to the public telephone system.

A constraining factor on the level of service provided by networks based on telephone systems is the transmission speed. Public telephone systems can economically provide speeds of 2400 bits per second over normal dial-up lines. Using transmission speeds over 2400 bits per second is currently expensive because of the cost of the modems and/or the cost of exclusive use of telephone lines.

A private telephone system (PBX), i.e., one which provides local service in a building or a group of buildings, can economically provide higher transmission speeds of 9600 to 19200 bits per second. Current digital private telephone systems (DPBX), i.e., a PBX which is implemented as a digital system as opposed to an analog system, can make higher transmission speeds even more economical. However, there is currently no software available to provide the level of service of the personal computer network model described in Chapter 2.

In particular, a speed of 19200 bits per second is not sufficient to provide the complete file service of the model (i.e remote virtual disk attachment). While some DPBXs can provide transmission speeds greater than 19200 bits per second, the cost per personal computer connection is much greater than the cost of other types of personal computer networks. Moreover, the higher speeds available (usually less than 100,000 bits per second) are still not fast enough to provide the level of service of the personal computer network model.

There are three basic ways of implementing a personal computer network using a telephone system: personal computer to personal computer, personal computer to computer center, and personal computer to bulletin board. In each case, terminal emulation software is used on the personal computer for communication. Terminal emulation software usually provides the following functions.

1. The personal computer simulates the behavior of a computer terminal. In this mode, the user accesses the keyboard and views the display as though a computer terminal were being used. In many cases, the terminal simulated has a large set of commands for controlling the screen display and cursor. Terminals which are compatible with the character codes defined in FIPS PUB 1-2 are examples of terminals with large command sets.

2. The personal computer is able to record an interactive session, i.e., the complete dialogue between the personal computer (disguised as a terminal) and the remote system can be saved on the disk. This capability is not only useful for saving a record of an interactive session, but it also provides a means of downloading a text file from the remote system to the personal computer. In order to download a text file, the user enters a command to the remote system to display a text file on the screen and the file is recorded to disk.

3. The personal computer is able to upload a text file from its disk to the remote system. The user invokes a text editor on the remote system and then commands the personal computer to send each character of the text file to the remote system. The remote system *thinks* that the user is typing the text on the keyboard of a terminal. Some terminal emulation software is able to enhance this deception by waiting for a prompt from the remote system after each line is sent before sending the next line.

4. The personal computer is able to transfer both text and binary files between itself and the remote system by means of an elementary public domain protocol. This is only

File Service	Print Service	Mail	Login	Remote Task Execution	Messaging & Conferencing	Outside Communication	Network Configuration
√			√		√	**√**	√

√ ⇒ full functionality

√ ⇒ full functionality not usually implemented

Table 3.1: Features of a personal computer to personal computer network

possible if the remote system is able to understand the protocol. Transferring a file by the methods described above has two basic limitations. First, it will not transfer binary data, only text data. Second, there is no guarantee that the data transferred will traverse the communication medium intact. Public domain protocols such as XMODEM and Kermit permit the transfer of both text and binary files. Moreover, when errors are detected in transmission, XMODEM and Kermit retransmit the data automatically.

5. The personal computer is able to dial into the telephone system and initiate a connection to a remote system. Some terminal emulation software is also able to keep an electronic phone directory. In addition, some terminal emulation software is able to answer a phone call, thus eliminating human intervention in completing a connection to a remote system which can dial.

Personal computer networks using telephone systems are configurable. Since virtually all computer and network services are available through a telephone system, if one service is not operational, the personal computer user can connect to another. Moreover, personal computer networks based on telephone systems are able to connect personal computers from different manufacturers. However, in all personal computer networks based on telephone systems, file service is available only in the form of simple file transfer. Because of the slow speeds of telephone systems, a remote virtual disk capability is not practical.

By means of terminal emulation software and a telephone system, a personal computer can be connected to another personal computer. Table 3.1 shows the capabilities of such a network. Both text and binary files can be reliably transferred even if the personal computers are from different producers. While the personal computers are connected,

File Service	Print Service	Mail	Login	Remote Task Execution	Messaging & Conferencing	Outside Communication	Network Configuration
√	√	√	√	√	√	√	√

√ ⇒ full functionality

√ ⇒ full functionality not usually implemented

Table 3.2: Features of a personal computer to computer center network

messages can be sent between the users. If the telephone system permits conference calls, several personal computers can be connected together and a message typed on one personal computer is broadcast to all. By running *remote console* software on a remote personal computer, a user is able to login to the remote personal computer as though the user were sitting at the keyboard/display of the remote personal computer. Such *remote console* software transfers user control of a personal computer from the keyboard/display to a communications interface. In a network of personal computers based on a telephone system, neither mail nor remote task execution is normally possible.

Telephone systems can also be used to connect personal computers to a computer center. Such a connection is often referred to as a *micro-mainframe* connection. Table 3.2 provides a summary of the features of this type of telephone network. File transfers are only between the personal computer and the central computer, not directly from personal computer to personal computer. If a user wishes to access a file located on another user's personal computer, the file must first be transmitted to the central computer.

Mail service is provided by the central computer which acts as a post office, each user having an individual post office box. There is usually no direct mail pickup or delivery on the personal computer. Login and remote task execution are usually only available on the central computer. Messaging and outside communications are also provided by the computer center. Since the communication system is a telephone system, should the computer center not be available, the user can still access services on a direct personal computer to personal computer basis or from another computer center.

The final personal computer network based on a telephone system is the connection of a personal computer to a *bulletin board* system. Table 3.3 summarizes the capabilities of this type of network. A *bulletin board* system is a personal computer running software

File Service	Print Service	Mail	Login	Remote Task Execution	Messaging & Conferencing	Outside Communication	Network Configuration
√		√				√	√

√ ⇒ full functionality

√ ⇒ full functionality not usually implemented

Table 3.3: Features of a personal computer to bulletin board network

which will allow users to post messages to a public mailbox and read messages left by others in the public mailbox. A bulletin board system also often acts as a repository for public domain software. This type of network is very similar in concept to the personal computer to computer center network already mentioned but with less capability. File service and mail may be provided in the same manner. The major difference is in the lack of any capability for print service, login, remote task execution, and messaging. The reason for this is the inablilty of most bulletin board software to connect to more than one personal computer at a time.

3.2 Direct Wire to Computer Center

Most organizations with mainframes and/or minicomputers have cabling already in place to support the direct connection of a terminal to their timesharing systems. Using a personal computer instead of a terminal at one of the connections provides access to the services of the computer center in the same manner as connecting a personal computer to a computer center by means of a telephone system. The transmission speed of a direct wire connection is often 9600 bits per second. As mentioned in Section 3.1, a transmission speed of 9600 bits per second is not sufficient to provide the level of service described for the personal computer network model.

Table 3.4 shows the features of this type of network. Since the personal computer is no longer connected to the computer center by means of a telephone system, the user is totally dependent on the computer center for providing outside communications. In many cases, the computer center does provide access to the public telephone system. In addition,

File Service	Print Service	Mail	Login	Remote Task Execution	Messaging & Conferencing	Outside Communication	Network Configuration
√	√	√	√	√	√	√	√

√ ⇒ full functionality

√ ⇒ full functionality not usually implemented

Table 3.4: Features of a direct wire to computer center network

many computer centers are directly connected to a network designed for large computers. However, if the computer center should become unavailable, then the personal computer becomes completely cut off. A prudent approach to connecting to a computer center by means of direct wire is to have a modem also attached to the personal computer in the event of computer center failure.

3.3 Network Designed for Large Computers

There are usually two possible ways of connecting a personal computer to a network designed for large computers. These computer networks were designed to provide a communication link for a terminal to a large computer, or for one large computer to another. The personal computer is neither a terminal nor a large computer, but can function as a terminal and except for speed, is a general purpose computer. Thus, a personal computer can always be attached to a network designed for large computers as a terminal and in many cases, can be attached as a computer (perhaps with limited functionality) assuming the network speed is not too fast and the network protocols not too complicated.

It is usually desirable to attach the personal computer as a computer since this normally guarantees the personal computer the capability of binary file transfer on the network. Whatever other services are available depends on the resources on the network and the extent to which the protocols can be implemented on the personal computer. However, networks designed for large computers normally only provide the Telnet, FTP, and mail services described in Chapter 1.

Table 3.5 summarizes the features of this type of personal computer network. Print

File Service	Print Service	Mail	Login	Remote Task Execution	Messaging & Conferencing	Outside Communication	Network Configuration
√	√	√	√	√	√	√	√

√ ⇒ full functionality

√ ⇒ full functionality not usually implemented

Table 3.5: Features of a network designed for large computers

service, remote task execution, messaging, and outside communication are normally provided by the large multi-user systems on the network. In terms of network configuration, the personal computer network based on a network designed for large computers usually has the advantage of being able to access more than one large computer on the network. Thus, if the user loses service because of the failure of a large system at one node, the user may restore service by accessing another node.

Chapter 4

Networks Designed for Personal Computers

Because personal computers have become so widespread within organizations, there are many networks designed specifically for personal computers. One of the key design goals for personal computer networks is to lower the per node cost of connection. In a network designed for large computers, the per node connection cost can be high since attached at each node is a powerful and expensive system which can simultaneously serve many users. A personal computer can cost less that $2000 and usually serves only a single user. Thus, the cost of attaching a personal computer to a network must be small. This is accomplished in network design by reducing the transmission speed, the maximum length of the network, and/or the maximum number of nodes which can be attached. In general, there is a direct relationship between each of these factors and the cost of the network. In this chapter, the services available on networks designed for personal computers are compared to those of the personal computer network model of Chapter 2. This comparison is followed by an extensive discussion of how network services are implemented on networks designed for personal computers.

4.1 Comparison with Network Model

As illustrated in Table 4.1, most networks designed for personal computers provide better service to personal computer users than ad hoc personal computer networks since satisfying the needs of personal computer users is the primary goal in implementing networks designed for personal computers. Thus, networks designed for personal computers are closer to the network model since it represents the expectations of personal computer users.

Almost all networks designed for personal computers provide the complete file service of the network model. Complete file service includes the capability of remote virtual disk connected to the user's personal computer and accessed as though it were attached locally. Once the user's personal computer is turned on and the remote virtual disks attached, the user can usually execute operating system commands and application programs no

File Service	Print Service	Mail	Login	Remote Task Execution	Messaging & Conferencing	Outside Communication	Network Configuration
√	√	√	√	√	√	√	√

√ ⇒ full functionality

√ ⇒ full functionality not usually implemented

Table 4.1: Features of a network designed for personal computers

differently than if the remote virtual disk were a hard disk volume physically attached to the personal computer. Not only is the means of access the same, the speed of a remote virtual disk will normally approximate the speed of a local hard disk and exceed that of a local floppy disk.

Some networks designed for personal computers support the connection of incompatible personal computers from different producers on the same network. For these networks, the complete file service of the network model may not be supported because the volume and file formats of the incompatible personal computers are significantly different. One personal computer's access to files created by another incompatible system on the network may be particularly awkward.

Most networks designed for personal computers provide the full print service of the personal computer network model. As is the case with remote virtual disks, the network provides access to remote printers as though they were connected locally. However, since the network spools the files to be printed, the user *prints* files using the network print service at a speed comparable to copying files to a remote virtual disk. Thus, the user's personal computer quickly becomes available for use. The network print service operates the printers for all users.

Almost all networks designed for personal computers provide mail service. However, mail service is usually not the *direct delivery* mail service of the network model. Users must access a remote network *post office* to send and receive mail. Moreover, users must initiate a request to the *post office* to see if they have any mail instead of having the option of being notified immediately upon the arrival of new mail.

Many networks designed for personal computers support some form of login, remote task execution, and messaging and conferencing. However, in many cases, these network

services are only provided if there is a minicomputer or mainframe attached to the network. The personal computer user is provided the ability to log into the remote large computer which provides these services in the same manner as any other interactive user.

Most networks designed for personal computers provide outside communications in the form of a dial in/dial out service. This service can normally be used to access both public and private telephone systems. By means of the telephone system, other networks designed for personal computers, networks designed for large computers, computer centers, and timesharing services can be accessed. However, some networks designed for personal computers provide direct access to other computer networks at much greater speeds than are possible when access is made through a telephone system.

Almost all networks designed for personal computers provide some capabilities for network configuration. However, the degree of configuration flexibility varies widely between implementations. Most implementations provide the capability of distributing services among network nodes. Many implementions support the connection of incompatible personal computers from different producers. Some implementations support the connection of minicomputers and mainframes to the network.

4.2 Implementations

This section provides additional detail concerning the capabilities of networks designed for personal computers by examining the methods used to implement network services. One of the design goals of almost all networks designed for personal computers is that only personal computers need be attached to the network in order to provide all network services.

4.2.1 Servers

Most of the services of networks designed for personal computers are delivered by means of network servers which are computer systems configured to provide network services. In most instances, the servers themselves can be personal computers. However, the servers may often be minicomputers, mainframes, or specially designed large microcomputers with large mass storage capacity. Mechanisms for gaining access to services include logging into the server and/or logging into the specific service desired. In the first case, the user identifies the desired server and gives a password. Once logged into the server, the user has access to all services on the server. In the second case, the user identifies the desired service (and perhaps also the server on which it is located) and gives a password. Once logged into the service, the user has access to only that service on the server.

An important characteristic of a network server is the extent to which it can be used locally while still functioning as a server. Some networks designed for personal computers require that systems used as servers be totally dedicated to that function and may not be used for any other purpose. The capability for both local and network use of a server is especially important when servers may be ordinary personal computers. This dual use

capability permits a number of existing personal computers which have a minimal need for network services (for example, simple file transfer and messaging) to be networked without requiring additional systems to be acquired for use as servers.

The services available on network servers include:

- File

  The file server is a central repository for files on the network. Files can be transferred from the file server to users' personal computers or from users' personal computers to the file server. While some file servers support file locking (i.e., the ability of a user personal computer to gain exclusive access to a file on the server), most do not support record locking (i.e., the exclusive access to an individual record in a file on the server). This is an important concern to users who are interested in accessing database files on the server simultaneously from several personal computers applying transactions to records in the database.

  Normally, a file server on a network designed for personal computers is provided by connecting a virtual disk on the server through the network to the personal computer. This virtual disk is accessed by the user through the network in the same manner as any disk drive local to the system and directly connected to it.

- Print

  The print server queues files to be printed on a printer selected by the user. Attached to the print server are printers, such as a laser printer capable of high quality text and graphics output, which are too expensive to be attached to every user system.

  There are a number of problems associated with current print services on networks designed for personal computers. An application program may not produce a print file which can be transmitted to the remote print server (i.e., the application program can only print directly on a printer attached locally). On the other hand, an application program may produce a print file that can be transmitted to the remote print server but cannot be printed on the server. A print file produced by an application may have a format which requires special utility software in order to output the print file to the printer. In many cases, the print server is not able to make use of such special utility software. Print servers typically are limited in the number and selection of printers which can be attached, and in the number of file formats which they can print.

- Mail

  Mail service is almost always provided by means of a mail server. Unlike the kind of service where mail is delivered directly to a user's personal computer, the mail server functions as a post office where each user has a post office box. In many cases, notification of pending mail is only given when the user logs into the mail server, i.e.,

when the user checks his post office box at the post office. When the mail server is inoperable, there is no mail on the network.

- Multiple Servers

  Networks designed for personal computers may permit only one server to provide the basic file, print, and mail services. The ability to add servers is a concern since the frequency of requests from users may overwhelm a single server, especially in those cases where the single server is a personal computer.

  Many personal computer networks do permit more than one server. Each server may provide all services or be dedicated to only some services. For example, there may be several servers: one for file service, one for print service, and one for mail service.

  It may also be possible to have more than one file, print, or mail server. However, when there are multiple file servers, it may not be possible to simultaneously access more than one server at a time. For example, an application program may be on one file server and the data file to be processed on another. For those networks which only allow access to one server at a time, the user may be required to log into one server and copy the data file to his local disk volume. After logging out of the first server, the user must log into the other server to run the application. In the case of several mail servers, the user may have to log into each mail server to check for mail.

How the network identifies each user to the services of the server may also be a concern. The network may allow a single user name to be used for all servers (i.e., the user logs in with his name and the desired server and/or service). On the other hand, the network may require a different user name for each server (i.e., the user name identifies not only the user but also the desired server and/or service).

4.2.2 Services Provided without Servers

Most networks designed for personal computers use servers to provide file, print, and mail services. While print service, by its very nature, requires a server, there are aspects of file and mail service which could be provided directly from one personal computer to another without the need of an intermediate server. In addition, the network functions of messaging, login, and remote task execution can be provided completely on a personal computer to personal computer basis.

The file transfer aspect of file service can be provided on a personal computer to personal computer basis as long as the receiver is operational. Mail can also be delivered directly to a receiver's personal computer as long as it is operational. If the receiver is turned off, then the mail could be queued on the sender and an attempt to send the mail made automatically at some later time. Direct personal computer to personal computer mail delivery and file transfer may be provided on some networks. These capabilities

can provide a minimal level of service when the servers are down or when the number of requests for service diminishes the response time of the servers.

Messaging and login can be totally implemented on a personal computer to personal computer basis. In fact, messaging and login are more efficiently implemented in such a manner since passing information first to a server and then to another personal computer would generate unecessary traffic on the network. All networks which provide messaging do so by delivering the sender message directly to a receiver. If a server were at all involved it would be only to record the message or conference session. Almost no networks designed for personal computers provide remote login to an operational but unattended personal computer.

Finally, remote task execution can be implemented either on a personal computer to personal computer basis or by means of a server. If implemented on a personal computer to personal computer basis, then the capability will not be lost when the server is not available.

4.2.3 Configuration

Many networks designed for personal computers are limited in configuration flexibility. Most implement services exclusively by means of servers. These servers usually can be personal computers with special hardware (e.g., large hard disk). On those networks where multiple servers are permitted, the user may be permitted to access only one server at a time. The use of existing minicomputers or mainframes as servers is normally not supported. Access to minicomputers and mainframes on the network by personal computers is often only supported by means of terminal emulation (i.e., the personal computer is able to access the remote system as though it were a terminal) and rudimentary text file transfer.

One of the most significant configuration problems with networks designed for personal computers is the lack of support for personal computers from different producers. Information transfer between personal computers of different architectures is a difficult problem. Files may be formatted differently at both the operating system level and the application program level.

In the personal computer arena, the problem has been partially solved by the use of text files which have a standard format for the particular kind of data which the file contains (e.g., spreadsheet data). Ideally, a personal computer network would provide data transfer services between personal computers at the application level. Unfortunately, many available personal computer networks do not support in either hardware or software the interconnection of personal computers from different producers. As a result, even with the availability of standard format files for data interchange and file format conversion utilities, it may not be possible to transfer the data over the network between personal computers from different producers.

Gateways

Gateways interconnect different networks. Gateways on networks designed for personal computers are important for several reasons:

1. Gateways provide personal computers with access to other communication systems. For example, the personal computer network may have a gateway to a public or private telephone system. In those cases where a personal computer network is not supported by a mainframe, there may be a gateway to the mainframe's communications front end.

2. Gateways provide personal computers with access to other computer networks. Connecting different networks together is sometimes called *internetting*. An internet gateway can interconnect networks which have different protocols. Networks which were designed to interconnect systems from a single producer may be gatewayed to each other in order to provide communication between personal computers from different producers. Where a network designed for large computers already exists between large systems, it may be more effective in terms of the quality of service to the personal computer user to establish a personal computer network with a gateway to the existing network designed for large computers.

3. Because of the requirement for networks designed for personal computers to keep the cost of connection low, the network is usually limited in its length and number of nodes. Gateways are a means of expanding the communications system within these limitations. When a personal computer network is nearing its capacity, another personal computer network can be installed and gatewayed to the first. This procedure is particularly effective when it is planned such that the majority of the communication traffic is local to each gatewayed network.

The services available through a gateway are typically very limited. At the minimum, file transfer of both text and binary files is usually possible. While some gateways can provide protocol conversion between incompatible networks, they almost never provide any file format conversion at either the operating system level or the application level. Any format conversion must be done at the nodes either before or after transmission.

There are several ways of implementing gateways on a personal computer network. Gateways may be provided by the producer of the network or by a third party. As products based on formal network standards become available commercially, gateways may be implemented using components from several producers. Among the ways internetting may be accomplished are: user connected to multiple networks, different logical networks on the same physical links, server gateways, and computer center gateways.

A rudimentary gateway can be implemented by connecting a single user personal computer to more than one network. This is possible only if the network interface hardware for each network can be connected simultaneously on the personal computer. For example, suppose that both the interface for network A and the interface for network B are boards

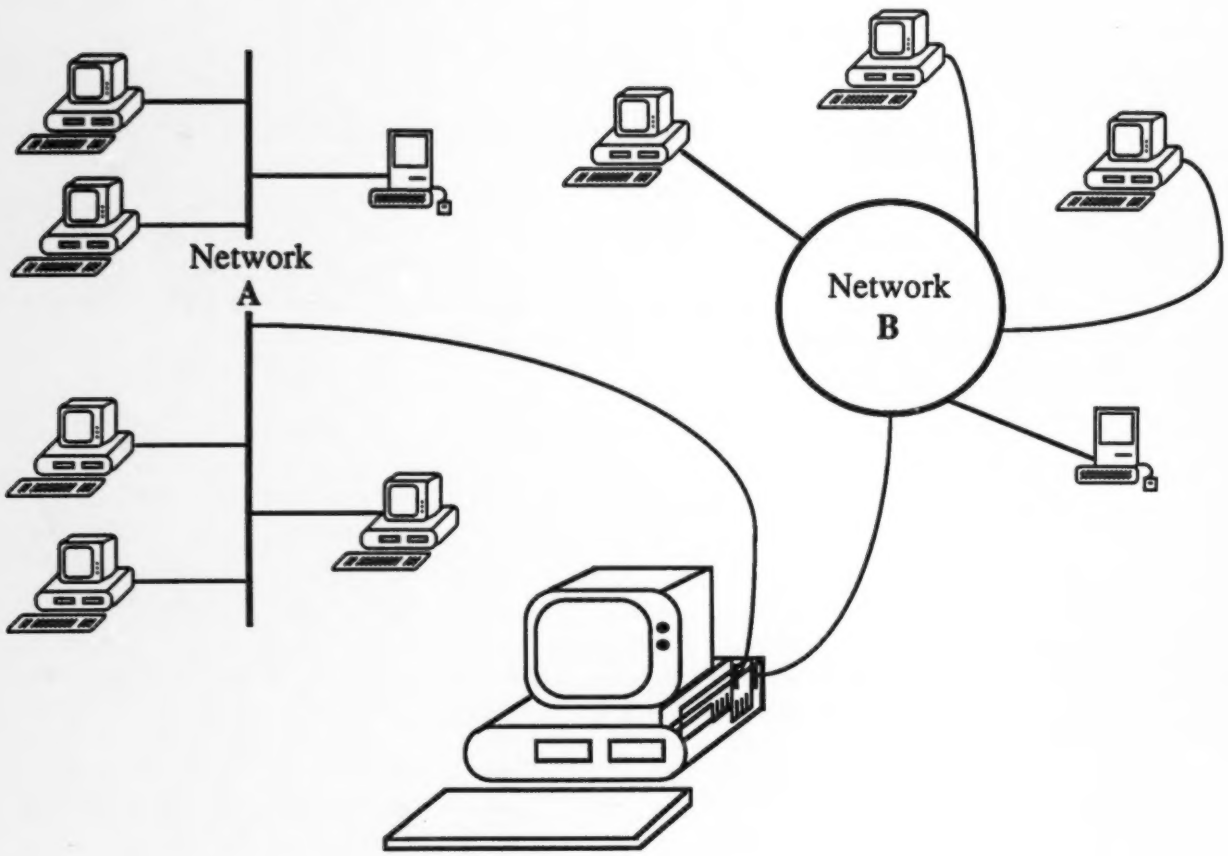

Figure 4.1: User connected to two personal computer networks

which are inserted into the personal computer as shown in Figure 4.1. The two boards may not be able to reside in the system at the same time, i.e., the system may not run under these conditions. Thus, the personal computer cannot be connected simultaneously to both networks.

In some cases, the user may be able to be active on both networks at the same time. However, it may be necessary to boot the personal computer with system software specifically for the network to be accessed. Even if only one network may be accessed at a time, it is still possible to accomplish a file transfer between networks. While connected to one network, the user can copy a file from that network to a local disk. In order to transfer the file to the other network, the system software for the other network must be booted and the file copied from the local disk to the other network. Typically, this procedure of copying a file from one network to another is complicated and not for the naive user.

A personal computer can also be used as a gateway between a personal computer network and a telephone system. A personal computer can be connected to the telephone system by means of a modem on a serial interface. This kind of gateway between a telephone system and a personal computer network is almost always possible since the serial port on the personal computer does not interfere with the hardware interface of

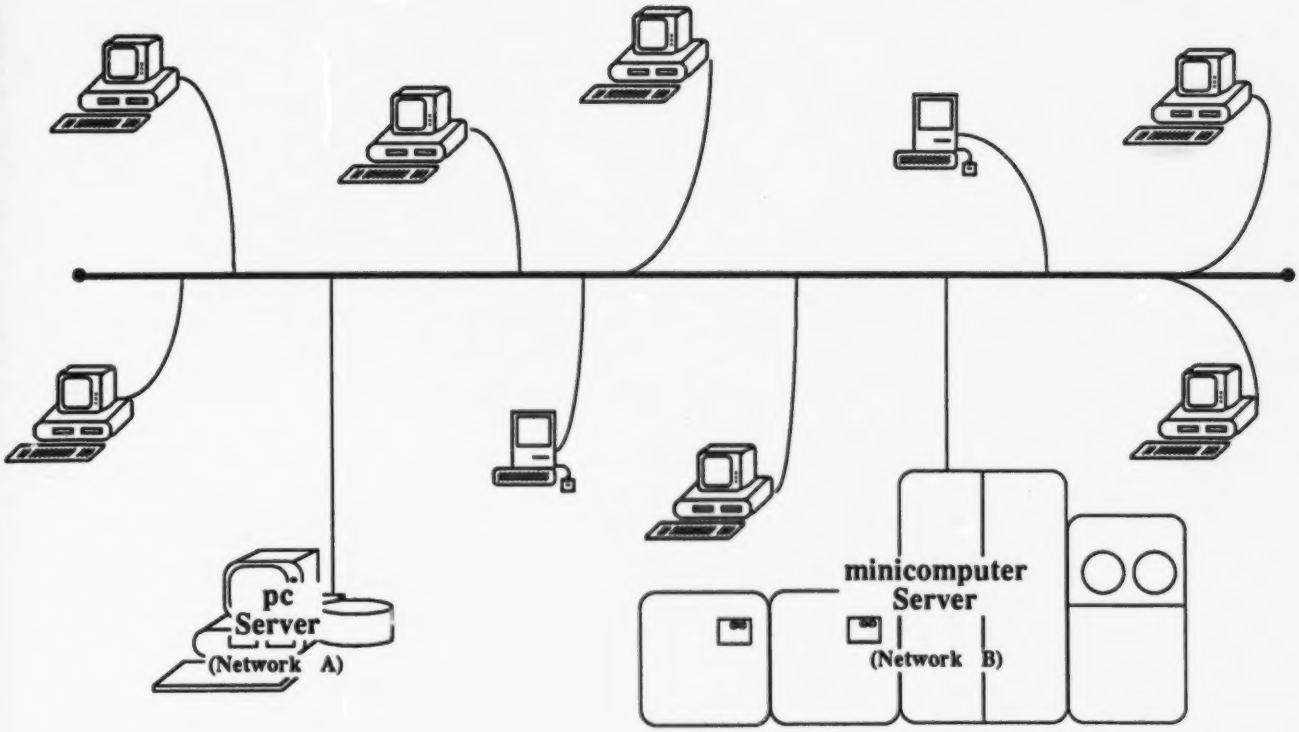

Figure 4.2: Two *logical networks* on the same physical link

most networks.

Different *Logical Networks* on the Same Physical Links

Another interesting configuration feature can be achieved by combining network hardware and software components from different producers, namely, more than one *logical network* can be implemented on the same communication hardware. Each logical network has its own data units transmitted over the same physical media. The data units for each logical network have different formats but the same functionality.

For example, a personal computer network may be implemented using the local area network standard defined in FIPS PUB 107. As illustrated in Figure 4.2, one group of nodes may be using data unit format **A** and another group of nodes may be using data unit format **B**. In Figure 4.2, there is a minicomputer acting as a server on the **B** network and a personal computer which is configured as a server on the **A** network. The communication medium is as specified in FIPS PUB 107. Because the data unit formats are different, there are really two logical networks even though they may use the same hardware. A personal computer running software that interprets **A** data units ignores the **B** data units while a personal computer interpreting **B** data units ignores the **A** data units. However, both personal computers are physically interfaced to the same cable.

Like the previous approach, this is another technique for connecting a personal computer to more than one network. However, in this case, the personal computer needs only one physical connection to access more than one network. In the previous approach, the personal computer was interfaced in hardware to two networks by means of two hardware interfaces. Nevertheless, when trying to do a file transfer between networks, the user must often boot the proper system software to access the desired network. Despite the fact that the personal computer is interfaced to only one physical communication system, it usually cannot have simultaneous access to more than one net since there is only one hardware interface. In the example illustrated by Figure 4.2, a personal computer which has loaded software to access the **B** network may only use the minicomputer as a server. A personal computer which has loaded software for the **A** network may only use the personal computer configured as a server.

Server Gateways

A server gateway on a personal computer network is a network server whose function is to provide a gateway service to another communication system. In this case, the user's personal computer is connected to only one network but it has access to another communication system almost as though it were directly connected. The server gateway provides whatever protocol and/or file format conversion is required to go between the personal computer network and the other communication system.

For example, a network server may provide protocol conversion between two networks as illustrated in Figure 4.3. When the gateway is between two networks, the level of service provided by the gateway can vary from just file transfer to full service depending on the level of compatibility of the network protocols and/or the level of compatibility of the systems on the networks.

Another example is a server which gateways a personal computer network and a telephone system. A server is connected to several autodial, autoanswer modems. A user's personal computer on the network is able to dial out through the server, or a personal computer or a terminal from a telephone system is able to dial into the network through the server.

If the network supports remote login, a dial out server can be implemented by installing on the network a personal computer connected to a modem. A user remotely executes a terminal emulation program on the dial out server which initiates the connection to the telephone system. Similarly, a dial in server can be implemented where the personal computer executes *remote console* software. A user calls the dial in server on the telephone system and is then able to access the network through the dial in server.

Computer Center Gateways

Very often, a network designed for personal computers may be connected to a minicomputer or a mainframe computer center which is also a node on a network designed for large computers. The large system usually is able to serve as an internet gateway between the

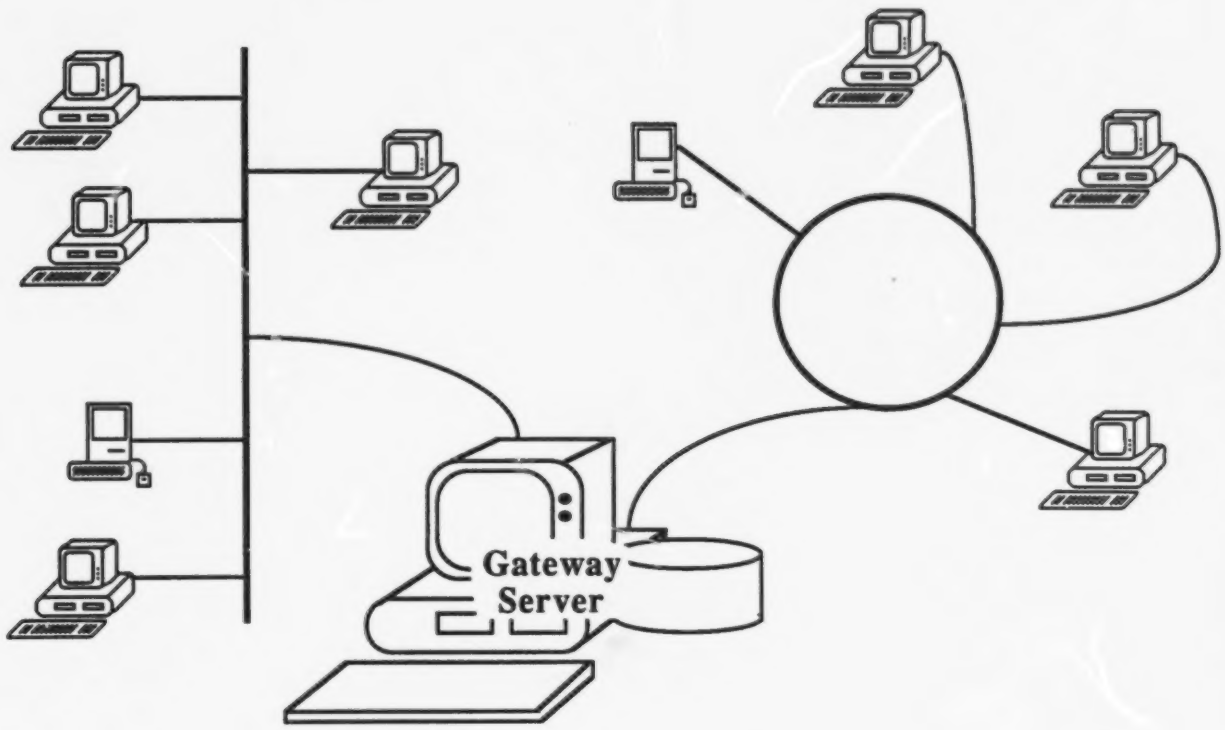

Figure 4.3: Communications server connecting two networks

personal computer network and the network designed for large computers. At the very least, the large system is able to connect a personal computer running terminal emulation to the network designed for large computers. In some cases, the level of internet service includes mail. The computer center may also serve as a gateway between personal computer networks.

4.2.4 Other Characteristics

There are several other characteristics of networks designed for personal computers which can be important. Among these are: network hardware, security and integrity, file backup, the integration of network software with personal computer software, and network management.

Network Hardware

The discussion in this section uses the model in Figure 4.4. In this model, network hardware consists of personal computers, network interfaces, and a communications backbone. Three aspects of personal computer network hardware are included in the discussion: the network interface connection to the personal computer, the topology of the communications backbone, and the network interface connection to the communications backbone.

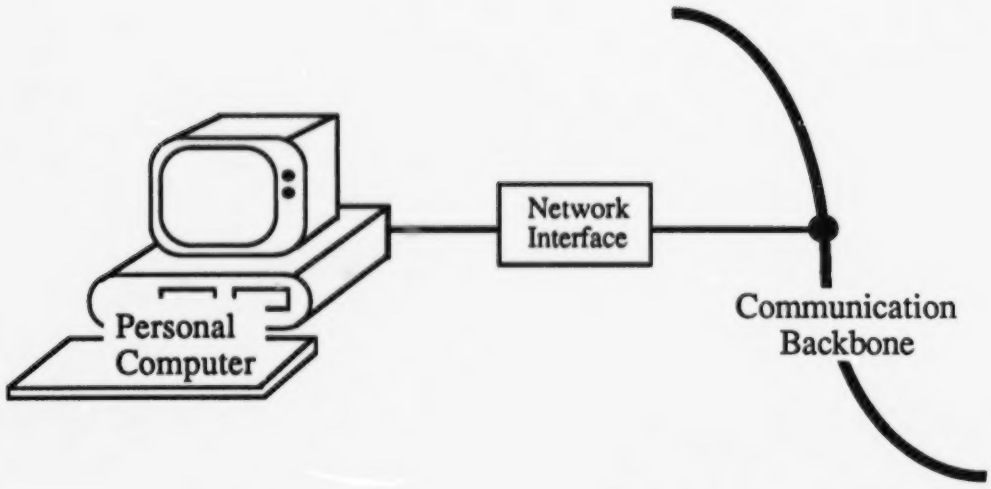

Figure 4.4: Personal computer network hardware model

Network interfaces are attached to personal computers either internally or externally as described in Figure 4.5. The simplest example of this is the connection of a personal computer to a telephone system by means of a modem. Modems can be external to the personal computer (i.e., a separate box which connects to a serial port) or they can be a board which is installed inside the personal computer. Most personal computers are able to have printed circuit boards inserted into a backplane bus. However, some have no capability for installing expansion devices internally. In which case, any additional hardware is installed external to the system.

Internal network interfaces are more difficult to install (i.e., may require a specialist) and are more likely to interfere with other hardware installed than an external network interface. A personal computer may be unable to connect to more than one network with internal interfaces because with both interfaces installed, the personal computer is unable to run. External interfaces can usually be connected and disconnected easily or attached to a switch so that a user's personal computer may access more than one network. On the other hand, internal interfaces usually allow higher transmission rates than external interfaces.

Another aspect of network hardware is the cable topology. Among the cable topologies used for personal computer networks are bus, ring, and connected stars as described in Figure 4.6. Many networks are based on a bus topology, in which each personal computer is directly connected to a cable bus. Unlike a ring topology, the bus topology has two ends which are not connected. Thus, a network cable can start at one end of a hall and end at the other without having to loop back on itself. With a connected star topology, personal computers are connected directly into a central hub and several hubs are connected with a bus.

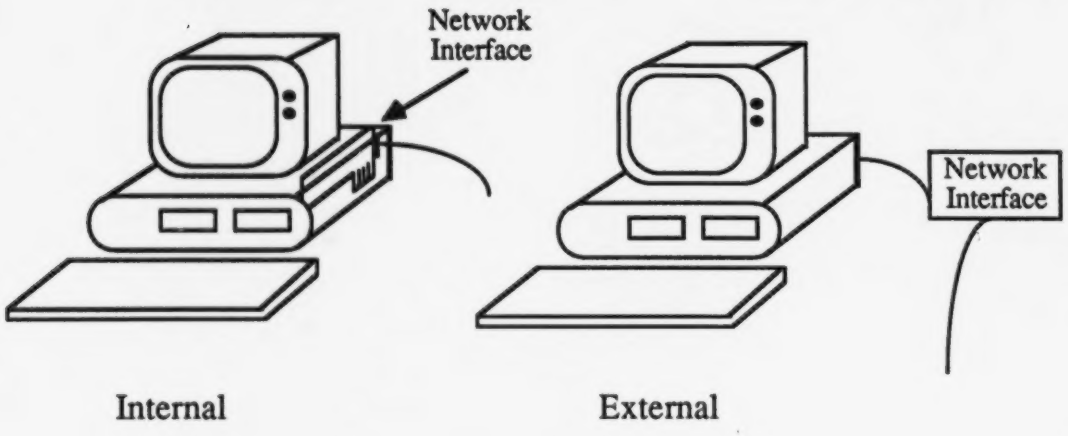

Figure 4.5: Internal and external network interfaces

In most cases, regardless of the topology of the commmunication backbone, the connection between a communication backbone and the network interface is by means of a cable as shown in Figure 4.7. At the interface, this connection is usually accomplished with a connector already installed on the interface. In some cases where the communication backbone topology is bus, the single cable which is the bus backbone must be looped to the personal computer network interface (also shown in Figure 4.7). In any case, when the personal computer interface is attached to the backbone, the ability of the backbone to transmit is interrupted. The network is non-operational during the time it takes to connect to the interface.

For example, many personal computer networks use a thick yellow cable for their communication backbone. Although very reliable, this cable is large, stiff, and difficult to manipulate. Attaching a connector to this cable is time consuming and requires a specialist; it certainly is not a task which could be done by a user.

Considerations in using personal computer networks include the difficulty in connecting a personal computer to the network, the level of skill necessary for the task, and the time the network will be down in order to make the connection. Another important consideration is the difficulty in reconfiguring the personal computer connections and the communications backbone in the event of an office rearrangement.

Security and Integrity

Computer security considerations for personal computers take on a new dimension when a personal computer is attached to a network, especially those networks where a user system may simultaneously provide services to other network users. For those networks whose services are provided by dedicated servers, the security and integrity considerations are similar to those of timeshared multi-user systems. For most of these networks all communications between users' personal computers is through dedicated servers which are

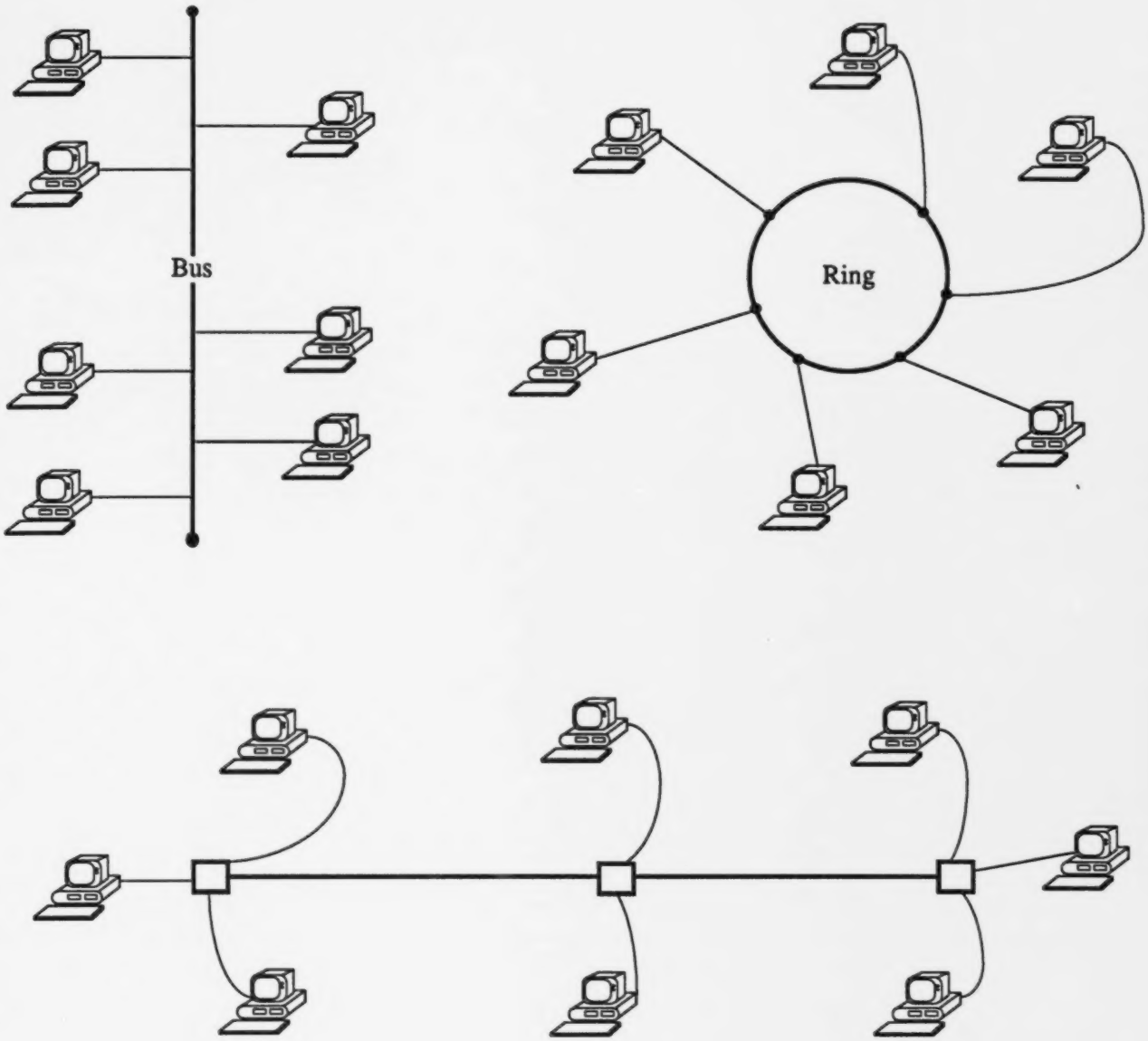

Figure 4.6: Communication backbone cable topologies

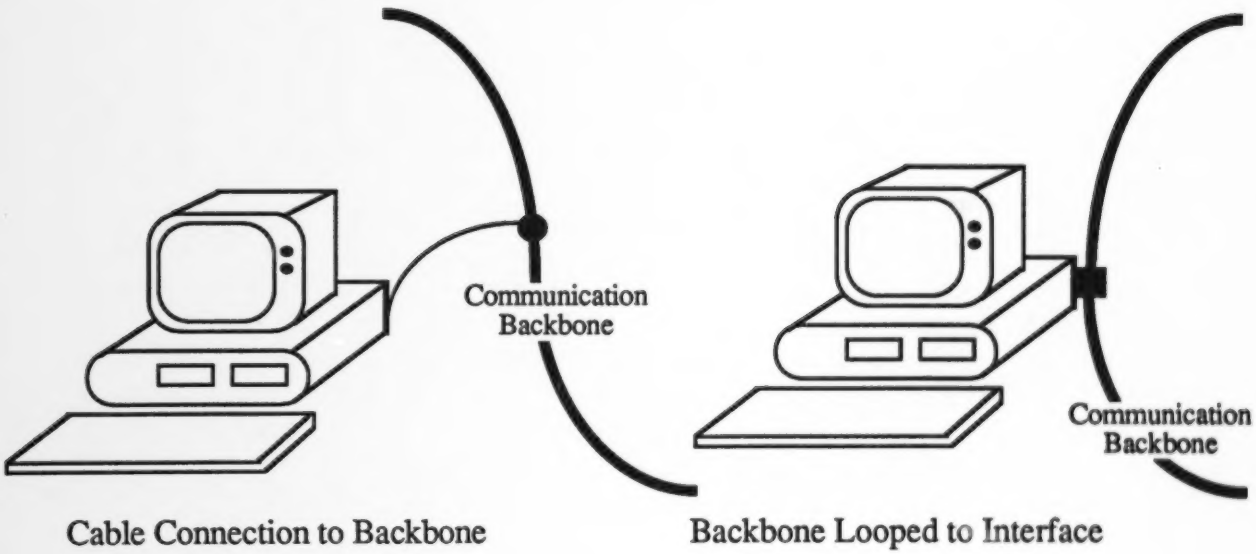

Figure 4.7: Connecting the interface with a bus backbone

responsible for maintaining security and integrity. Nevertheless, the ability of the network to protect users' files on a server from intrusion or destruction is usually considerably less in a personal computer network than in the average large timeshared system. In those networks where services are delivered by user systems, data security and integrity is usually even less than that in the dedicated server networks.

File Backup

An important consideration is how file backups are accomplished on the network. File backup can be left to the user or can be a service of the network. When file backup is a network service, the dimensions of the task are similar to the task of file backup in a computer center. However, file server software on the network usually does not include efficient backup utilities which are usually available on large computers. For example, it may not be possible to easily restore only a few files which may have been lost without restoring the entire disk.

This lack of efficient backup utilities can make the task of providing a backup service on the network difficult. For example, with some personal computer networks, it may be necessary to deny users access to the network while backup procedures are performed. Another example is that file backup may only be accomplished by transmitting them over the network causing greatly increased traffic and in most cases, increasing the time to do backup.

Integration of Network Software with Personal Computer Software

The personal computer network is almost always produced by someone other than the producer(s) of the personal computer software. This is almost always the case for application programs and often the case for operating system software. Application programs may not be able to be stored on or run from servers. This constraint may not have anything to do with licensing. As long as each user system is licensed, most software producers do not object to storing and executing application programs from a server. The manner in which the application program was implemented may make it technically impossible to download the application from a server and run it locally on a personal computer. Fortunately, as networks designed for personal computers become more common, many application software producers are making available versions of their software tailored to be run on networks designed for personal computers. In particular, data base packages which permit the update in real time of shared data base files on network virtual disks are becoming available.

Where the network producer is someone different from the producer of the personal computer operating system software, the network producer may have impacted the personal computer operating system in less than desirable ways. The result often is that certain applications or system utilities may not be able to run on either a personal computer or a server. This can happen because the network software modifies the operating system software on both the user's system and the server system.

For example, the network may structure files and directories differently from the way the personal computer operating system does. The result is that files created using the network may only be accessible through the network. Suppose an operating system utility were used to copy a file from a disk on a personal computer through the network to a virtual disk on a server. That file on the virtual disk may be inaccessible to the same utility should the server be shutdown and an attempt made to access the file directly on the server.

Management

Many organizations consider a personal computer the responsibility of the individual user and thus provide only minimal support. Users must provide themselves many of the services provided by most computer centers (e.g., file backup). When personal computers are networked, this approach may become no longer feasible except for small groups of advanced users. For any network to provide service, the network must be supported and managed since it is a resource shared by all users. In many ways, a personal computer network with servers is very similar to a computer center and may usually be viewed as such.

However, there are operational considerations related to networks designed for personal computers which may differ from operational considerations in computer centers and networks designed for personal computers. Among these are installation of new connections, maintenance of the communication backbone, and maintenance of the server(s).

In many cases, it is possible for users to install their own network connection, especially in those cases where the personal computer interface is external. However, personal computer network connection by users may not be desirable for several reasons. The network interface hardware and/or software may have to be configured in specific ways depending on the other hardware and software components in the user's personal computer. Since personal computer hardware and software is usually from several different producers, the documentation rarely addresses specific combinations. In addition, the installation of most personal computer network connections interrupts communications on the communication backbone. In those cases where such an interruption occurs, it is best that the connection be made as quickly as possible and at times when the interruption of service has the least impact.

Another operational consideration with networks designed for personal computers is the maintenance of the communication backbone. An important aspect of communication backbone maintenance is preserving the integrity of the communication backbone so that messages can be transmitted reliably. When the network fails, diagnosing network failure requires that the following types of questions be answered: has the cable failed and where? has a personal computer on the network failed, flooding the network with messages? has a server failed? Users are usually not able to make such determinations. Another aspect of communication backbone maintenance is the reconfiguration of network connections. A common occurance in an office environment is the relocation of individuals or the rearrangement of entire office spaces. The network connections of the users who are moved must be reconfigured. Users are usually not able to undertake such a reconfiguration.

There are many aspects to server maintenance including user account management, file backup, disk space management, printer management, and mail management. The problems associated with server maintenance are specific to each network. Some examples of possible problems are:

1. A user account providing access to the services on a server must be created or removed. This operation may not be possible while the server is providing service on the network.

2. The network may be down and a user may need to access a file which was on the server. This file is available from a network server backup diskette. However, because the format of the file on the network backup diskette is different from the format used by the operating system, the user is unable to read the backup diskette except through a network server.

3. It is often the case with networks designed for personal computers that a user can allocate for his exclusive use as much disk space on a server as desired. Consequently, file service space must be managed manually.

4. The printer on a print server may run out of ribbon and stop. As a consequence, storage space allocated on the print server for storage of print files waiting to be printed may become exhausted and have to be cleared before print service is resumed.

5. Space on disk assigned for intermediate storage of mail messages may become exausted and have to be cleared before mail service can be resumed.

Chapter 5

Summary

In Chapter 2 a personal computer network model was described. This model provided the kinds of network services specifically designed to meet the needs of a personal computer user. As mentioned in Chapter 2, the needs of a personal computer user for network services can differ significantly from the needs of a terminal user connected to a large multi-user system. The terminal user's needs are met by networks designed for large computers as discussed in Chapter 1. The personal computer user's needs for network services can be met by networks designed for personal computers or by ad hoc personal computer networks. The personal computer user must also have access to other networks and this access is again provided in the personal computer network model.

5.1 Current Implementations

Chapter 3 and Chapter 4 discussed the limitations of current personal computer networks and how they fall short of what may be expected. Table 5.1 shows a comparison of all of the kinds of personal computer networks mentioned in Chapter 3 and Chapter 4 to the personal computer network model of Chapter 2.

All personal computer networks provide a facility for transferring files. This capability is fundamental to the notion of two personal computers communicating with each other. The more complete file service of the personal computer network model takes the form of allowing a virtual disk on a remote system to be used by a personal computer as though the virtual disk were directly attached locally. Most networks based on telephone systems provide only simple file transfer. Most networks designed for large computers and networks based on direct wire to a computer center also provide only simple file transfer. For each file to be transferred, the user must enter the name. It is usually not possible to have several files transferred with one command. Networks designed for personal computers always provide for easy access to remote *virtual* disks.

The full print service of the personal computer network model (i.e., print spooling) is always available for those kinds of networks where a personal computer can access a large multi-user system as is the case for a personal computer connected to a computer center

Feature	Ad Hoc personal computer Networks based on Telephone Systems: pc to pc	Ad Hoc personal computer Networks based on Telephone Systems: pc to Computer Center	Ad Hoc personal computer Networks based on Telephone Systems: pc to Bulletin Board	Direct Wire to Computer Center	Networks Designed for Large Computers	Networks Designed for personal computers
File Service	√	√	√	√	√	**√**
Print Service		**√**		**√**	**√**	**√**
Mail		√	√	√	√	√
Login	√	√		√	√	√
Remote Task Execution		√		√	√	√
Messaging & Conferencing	√	√		√	√	√
Outside Communications	**√**	**√**	**√**	√	√	√
Network Configuration	√	√	√	√	√	√

√ ⇒ full functionality

√ ⇒ full functionality not usually implemented

Table 5.1: Features of current personal computer networks

or to a network designed for large computers. The user need only transfer the file to the large system and then use the print service of the large system. In addition, all networks designed for personal computers provide complete print service in one of two ways. If the network permits the attachment of a large system, then the user can print files in the manner described above. Additionally, networks designed for personal computers support the attachment of a personal computer designated as a print server which provides full print service.

The mail of the personal computer network model is usually not available on any personal computer network. Mail is almost never delivered directly to the receiver without using a central *post office*. All personal computer networks use a designated system on the network as a post office. In the case of a personal computer connected to a computer center, to a bulletin board, or to a network designed for large computers, the central computer,

bulletin board, or a large system on the network designed for large computers is the post office. The user must access a large system and check for mail. Users must solicit for any notification on their personal computers that mail was received. Mail to be sent must be transferred to the *post office* in order to be *mailed*. When the network is one designed for personal computers, either a large system or a specially configured personal computer becomes the post office and is refered to as a *mail server*. However, the functionality of a mail server is essentially the same as that of a large system used as a post office except that it is easier to transfer the mail between the user's personal computer and a mail server.

The login capability of the personal computer network model is normally only available where a large system can be part of the personal computer network. Few personal computer networks support the direct login of one personal computer to another. When a large system is part of the network, login is usually accomplished by running terminal emulation software on the personal computer and accessing the large system as though the personal computer were a terminal.

Remote task execution is potentially available whenever login to a large system is available and the large system supports the execution of operating system command files. Users log into the remote large system, transfer a command file from their personal computer, and start the command file's execution. Some networks designed for personal computers also support remote task execution by means of a personal computer configured as a task execution server. However, the server can only execute a single command file at a time. Command files received by the server while it is currently processing a command file are either queued or rejected.

Messaging and conferencing may be available on all types of personal computer networks except in the case of a personal computer connected to a bulletin board. Most bulletin board software does not support multiple simultaneous access. Thus, messaging is not possible. In all other types of personal computer networks, some form of messaging and conferencing may be available. For those networks which connect personal computers to a computer center (including networks designed for large computers and those networks designed for personal computers which have a large system attached), messaging and conferencing may be implemented by special software in a central large system. For those networks designed for personal computers which do not have a large system attached, messaging and conferencing must be implemented in a direct personal computer to personal computer manner.

The ability to access outside communications is usually available on all personal computer networks in some form. When the personal computer is directly connected to a telephone system, the user has access to every computer center or network reachable by telephone. Where the personal computer is only directly attached to a computer center or network, the user must rely on the network or computer center for outside communications.

The flexibility of the personal computer network model for network configuration is usually not fully available on any personal computer network. However, some flexibility is available on all personal computer networks. It is very much dependent on the technical specifications of an individual network. While it is usually straightforward to determine

which personal computers can be connected to a network, the flexibility of the network in distributing services across nodes can be difficult to ascertain.

5.2 Future Implementations

Because the personal computer network model is technologically feasible, i.e., each capability exists in a real network, it is reasonable to conclude that a personal computer network like the model will be realized in the not too distant future. How will current network implementations evolve into the model? Insights into this question can be made by considering the following scenarios:

- A Single Set of Formal Network Standards

  The personal computer network model is implemented using a set of formal network standards which are drawn only from the formal standards arena, i.e., standards agreed to by all participating producers and users. In this scenario, a network is implemented by choosing the best components from several producers. A component from one producer fits with a component from another producer because each meets the single set of standards. Every computer system can be connected to the network.

  Work at both the national and international level with active ICST participation is resulting in the development of network protocol standards. These formal standards are based on the International Organization for Standardization (ISO) Open Systems Interconnection (OSI) model. Formal standards based on the seven-layer OSI network model specify the protocols and services for communication across a network. The seven layers included in the model describe in a modular fashion the various functional parts of the communication process from layer one, the hardware layer, up through layer seven, the application layer.

  The user interface is located within the application layer. Examples of ISO standards activities related to how users access networks include specifications for: File Transfer and Management (FTAM), which defines some of the file service capabilities of the personal computer network model; Virtual Terminal Protocol (VTP), which corresponds to the login feature of the personal computer network model; and Job Transfer and Management (JTM), which corresponds the remote job execution capability of the personal computer network model.

  Existing networks which do not meet the single set of standards are connected to the standard with gateways, but, in the long term, the non-standard networks are expected to be phased out. The concept of gateways for the purpose of protocol conversion becomes obsolete. However, gateways are still necessary in order to interconnect standard networks which, in order to keep the cost more in line with the cost of personal computers, have restrictions on their length or number of nodes.

- Multiple Sets of Network *Standard*[1] Specifications

  During the period of waiting for adequate formal standards to be completed and available, the following scenario takes on significance. There are several sets of network *standard* specifications, a set of formal standards and several sets of defacto network *standards*. Gateways not only connect existing networks to a *standard* network but are also used to interconnect the *standard* networks. The personal computer network model is implemented either by choosing one set of network *standards* or by choosing several sets of network *standards* and interconnecting them with gateways. The scenario of one formal set of network standards implies that full service is available throughout the entire network. There are no fundamental incompatibilities to limit service across network boundaries. This scenario implies that because there are several sets of incompatible network *standards*, gateways must be used for the purpose of protocol conversion. Consequently, there may be service restrictions across network boundaries.

  Why then would an organization choose to install more than one set of network *standards*? Most organizations already have both large and small computers from more than one producer between which they wish to establish communications. Under this scenario, the only way to accomplish this may be to gateway more than one network since it may not be possible to connect all of the organization's systems to a single *standard* network.

- A Single Standard User Interface

  The scenario of multiple sets of network *standards* presumes that there can be a different user interface between two sets of *standard* networks. For each network, that the user accesses, a different language is used and different levels of service are provided. In this scenario, each of the *standard* networks provides the same level of service and the same command language. There is a single standard at the highest protocol layer (layer seven, the applications layer, in the OSI model) but there may be several sets of both formal and defacto *standards* at the lower protocol layers.

The question arises as to whether an organization should wait for networks which implement all or most of the personal computer network model or meet its needs in some limited way by using current implementations. If an investment in a personal computer network is made now, will this in the future preclude an organization's use of a network like the model because the network to come may have different protocols? In particular, will the formal network standards being developed become pervasive, making networks already installed obsolete?

Because of the continuing progress in both network technology and the network standardization effort, an organization may wish to see its networking of personal computers as an evolutionary process. There are several reasons for this view. Among them are:

[1] Italics implies an informal or in-house agreed-upon specification to be used as a standard.

1. A network like the personal computer network model is not available yet. If an organization has a need for a personal computer network and requires the level of service of the model, it must wait. If an organization cannot wait, then it must accept less service than is available in the model and it may wish to choose a personal computer network which is widely used. If a network has many installations, it is more likely that it will evolve into a network like the model. If it does not evolve, then it is more likely that there will be gateways to the networks with the features of the model.

2. Networks based on formal standards are not widely available at this time. In many cases, some formal standards have yet to be agreed upo. However, it is clear that there will be networks like the model available from many producers based on formal standards. This implies that there will be gateways between networks based on formal standards and many current networks.

3. An organization which has many personal computers already may not wish to make the investment in connecting all of its personal computers and larger systems together at one time. Many systems may not yet have a need to be connected. However, at some later time, it may be necessary to add them to an organization's network(s). From an economic standpoint, it may be more feasible to add systems to networks as they are needed and build the organization's intersystem communications capability incrementally.

4. The notion of what constitutes acceptable service in a personal computer network constantly changes. The personal computer network model described in Chapter 2 will probably become the commonly installed network of two years from now. One of the characteristics of the network model of Chapter 2 was that it was technologically feasible today but not fully implemented yet. Two years from now, a network which fully satisfies the a user's requirements and expectations may be considerably more capable than the one of Chapter 2.

Thus, networking within an organization is an ongoing activity. This activity, like any other so technology driven, must have a methodology for moving with the technology without disrupting the organization's primary objectives.

5.3 Networking Now

Personal computer networks can fulfill requirements for personal computer communication and peripheral sharing. Meeting these requirements can translate into improved productivity in the office. For example, the *Merlin* personal computer network system, which has been operational in the GSA's Western Region since July 1983, has led to significant improvements in both work output per employee and lower cost per unit of output. The discussion in Section 5.2 implies that, with informed planning, these productivity

gains can be achieved now with a minimum risk of being cut off from future technological developments.

The personal computer networking problem facing many organizations can roughly be described as follows:

> The organization has acquired many personal computers. The communication capabilities between these personal computers and large computers are crude to non-existant and the communication capabilities between the personal computers are worse. Terminal emulation is the principal method used for personal computers to communicate with large computers and the personal computers communicate with each other through the large computers. The capacity of the terminal communications facilities of the large computers is being overwhelmed by the demand for more lines into the computer centers and by the amounts of data flowing through these lines to and from the personal computers.
>
> The organization needs to provide some relief for its large computers from the communication demand placed on them by the personal computers. It cannot wait for a network like the personal computer network model to become commonplace. It needs to begin to provide some of the services of the model now.

One of the most difficult aspects of networking personal computers is the absence of a single, off-the-shelf solution to connecting the variety of personal computers, minicomputers, and mainframes that an organization may have to a single network. For example, personal computers can usually be connected to networks designed for large computers but the only services provided are simple file transfer and login to a large system. Large computers on a network designed for large computers cannot usually provide the more sophisticated file service needed by personal computers. Such full file service is usually only available on networks designed for personal computers. However, large computers can usually not be connected to such a network for personal computers.

With the help of research into communication technology, and a survey of available commercial and public domain products, some solutions to networking problems can often be found. By combining available hardware and software components, it is possible to interconnect most personal computers, minicomputers, and mainframes. For example:

1. Users need the complete file service of a network designed for personal computers and also need to be able to access several computer centers interconnected on a network designed for large computers. Personal computers and file servers for a network designed for personal computers are physically connected to the communication backbone of the network designed for large computers. The network designed for personal computers and the network designed for large computers share the same communication hardware. Users access one network at a time on their personal computers by running appropriate software for the chosen network. (See Chapter 4, Section 4.2.3)

2. Users on one network designed for personal computers need to be connected to another network, but their personal computers cannot be connected to the other network because the other network only supports personal computers from a different producer. A server gateway is attached to both networks and provides simple file transfer between the two networks. (See Chapter 4, Section 4.2.3)

3. A user needs to be connected to more than one network. The user's personal computer is physically connected to both networks. The user accesses one network at a time by running software appropriate for the chosen network. (See Chapter 4, Section 4.2.3)

Because of the variety of communications systems currently in use, gateways are the most common means of interconnecting incompatible computer systems. Thus, computers which cannot communicate directly with each other on a single network, can be linked together by means of a gateway between two networks.

Unfortunately, the use of off-the-shelf technology does not provide the features of the personal computer network model of Chapter 2 and in some cases, may not even provide the minimal capability necessary to be useful. An organization must provide the missing hardware and/or software components. In most cases, this is a non-trivial undertaking. Developing communication system components, hardware or software, is expensive, time consuming, and not for the inexperienced. There is great danger that the capability being developed may not be completed by the time a solution is available from other sources.

The ability to communicate between an organization's personal computers, minicomputers, and mainframes has become an important part of organization's ability to deliver its products and services. The personal computer network model provides a broad framework under which realistic requirements can be identified. From these requirements, several approaches, based on combining available commercial and/or public domain network components, can be found to meet the need. By an informed consideration of the limitations of each approach, a choice can be made which insures that the solution implemented today can evolve along with communication technology.

Appendix A

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Appendix B

Personal Computer Network Testbed

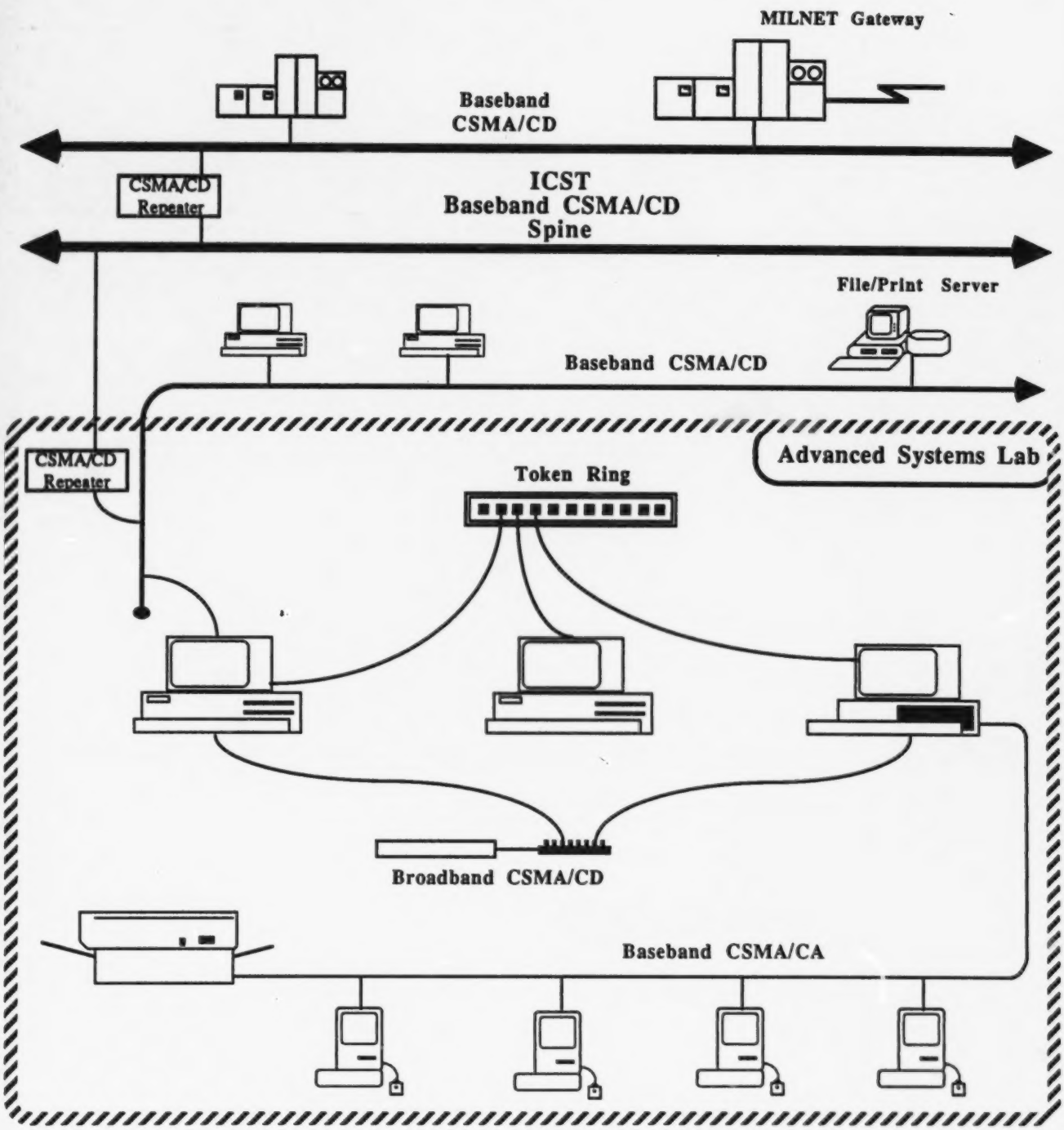

Figure B.1: Personal computer network testbed in the Advanced Systems Laboratory

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☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

Personal computers have been widely used in today's office to support clerical, administrative, and managerial functions. Because communication between individuals in a office and between groups in an organization is vital to the organization's ability to deliver products and services, it naturally follows that the personal computers used by the individuals in an office need to be able to communicate. Another organizational requirement which is often met by networking personal computers is that of data sharing.

This document presents a survey of personal computer network technology from the point of view of the end user. It characterizes the capabilities of personal computer networks and the services which they provide the user in terms of generic features. As a result, technical management and end users will have an understanding of how personal computer networks can fit into an overall office automation strategy. The document does not discuss or evaluate alternatives for the sharing of data, such as, the manual exchange of floppy disks between personal computers.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

Communications; computers; microcomputers; networks; office automation; personal computers.

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